Computerized Prediction of Extravehicular Activity Task Feasibility

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The difficulty of accomplishing work in extravehicular activity (EVA) is well documented. It arises as a result of motion restraints imposed by a pressurized spacesuit in a near-vacuum and of the frictionless environment induced in microgravity. The appropriate placement of foot restraints is crucial to ensuring that astronauts can remove and drive bolts, mate and demate connectors, and actuate levers. The location on structural members of the foot restraint sockets, to which the portable foot restraint is attached, must provide for an orientation of the restraint that affords the astronaut adequate visual and reach envelopes.

Previously, the initial location of these sockets was dependent upon the experienced designer's ability to estimate placement. The design was tested in a simulated zero-gravity environment; space-suited astronauts performed the tasks with mockups while submerged in water. Crew evaluation of the tasks based on these designs often indicated the bolt or other structure to which force needed to be applied was not within an acceptable work envelope, resulting in redesign. The development of improved methods for location of crew aids prior to testing would result in considerable savings to the design effort for EVA hardware. Such an effort to streamline EVA design is especially relevant to *International Space Station (ISS)* construction and maintenance. Assembly operations alone are expected to require in excess of 400 hr of EVA. Thus, techniques which conserve design resources for assembly missions can have significant impact.

An experiment has been conducted at Marshall to test the efficacy of a human modeling software package in placement of foot restraint sockets. An ISS assembly mission which is being managed as a Marshall payload was used as the experimental test situation. The mission is the delivery of the Space Station remote manipulator system to the U.S. Laboratory on Assembly Flight 6A. The robot will be carried to orbit in the orbiter payload bay on a Spacelab logistics pallet. CAD models of the space hardware, including the foot restraint, were incorporated into the package, and a model of the space suit was acquired and modified for the human model. Limits of motion were placed on the suit based on mobility studies published in NASA standards documentation.[1,2] A series of simulations was run, in which the astronaut model performed bolt-removal and cable-connection tasks from the foot restraint inserted into sockets placed on the hardware. Locations of the sockets based on these simulations were used to develop neutral buoyancy mockups. An evaluation of the design was conducted in the Marshall Neutral Buoyancy Simulator (NBS). A team of six astronauts rated each of the tasks for ease of accomplishment.

The foot restraint support is jointed to provide 4 degrees-of-freedom. It can thus be configured and oriented in different directions from a given socket. In the course of the modeling, 9 socket sites were identified to support the 17 tasks. The placement of the socket by modeling was considered successful if the astronaut evaluators rated the task as acceptable. The accuracy of the location of the sockets was 94 percent. This is a higher rate of reliability than is typically achieved; it resulted in a time-efficient test, and design changes after the test were minimized. In addition to simple placement of the sockets, the modelers attempted to predict the joint settings required to reach the task. Success in this effort results in reduction of test time and is used to develop on-orbit procedures. For the four settings, the astronaut evaluators made no changes 79, 78, 78, and 59 percent of the time; in these cases, the modeled predictions were accepted as correct. This level of accuracy was considered by the crew to be both high and valuable to test conduct. Marshall is now refining the models and will compare a new set of predictions with crew evaluations in an upcoming test at the NBS.

[1]NASA-STD-3000; vol. 1. Man-Systems Integration Standards, Rev. B, 1995.

[2]Pantermeuhl, J.D.: EMU Reach And Proximity Modeling Data. LMES-31732, Lockheed Engineering and Sciences Company, Houston, 1995.

Sponsor: Space Station Program Office/ Payload Projects Office

Other Involvement: Johnson Space Center

Biographical Sketch: Charles Dischinger is a human factors engineer in the Mission Training Division of the Mission Operations Laboratory. He is responsible for human/ machine interface design for Marshall payloads. He received the M.S. degree in biology from West Virginia University in 1981 and has worked for Marshall for 2 years.